FISH LETHALITY AND TAINTING
IN
THE OTTAWA RIVER IN THE VICINITY
OF THE
CANADIAN INTERNATIONAL PAPER MILL
HAWKESBURY, ONTARIO

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Ontario
Ministry of the Environment

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FISH LETHALITY AND TAINTING

IN

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CANADIAN INTERNATIONAL PAPER MILL,

HAWKESBURY, ONTARIO

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Toxicity Unit

Quality Protection Section

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I. SUMMARY

As part of a Ministry assessment of the environmental impact of the Canadian International Paper mill effluent at Hawkesbury Ontario, fish toxicity tests were carried out in the Ottawa River, downstream of the mill discharge.

Caged rainbow trout were exposed to the effluent plume in the Ottawa River for 2 to 4 days. Acute toxicity tests involving rainbow trout and daphnia were completed in the laboratory using the collected effluent samples.

The effluent was demonstrated to be acutely lethal to both rainbow trout and daphnia. A zone of lethality in the Ottawa River was observed to extend 900 meters downstream of the discharge. Caged rainbow trout were observed to be tainted after 48 hours exposure in the effluent plume as far as 2.5 kilometers downstream of the discharge.

Shortly after the completion of the Ministry field study, CIP ceased operations (December 1, 1982) at its Hawkesbury plant. Declines in market demands for cellophane and rayon resulted in the company being unable to sell 50% of its product and the soft economy was cited as the reason for closing.

II. INTRODUCTION

The Canadian International Paper (CIP) mill in Hawkesbury, Ontario has been discharging liquid waste into the Ottawa River since the late nineteenth century. Toxicity monitoring of the final effluent in 1977 and 1980 indicated that the waste was acutely lethal and regional office chemical data indicated little change in effluent quality.

This study was initiated at the request of the Ontario Ministry of the Environment's Southeastern Region as part of an overall assessment of the environmental impacts of this discharge.

In order to conclusively demonstrate any impact on the Ottawa River, bioassays using caged fish placed directly in the effluent plume were used for this study.

The objectives were:

1) determine the zone of acute fish lethality and
2) determine the zone of fish flesh tainting in the Ottawa River.

III. METHODS

(a) Study Sites

The final effluent from the CIP mill discharges through a diffuser in approximately ten feet of water midway between Hamilton Island and the shore of the Ottawa River (Figure 1). This channel receives only a small portion of the total flow of the river.

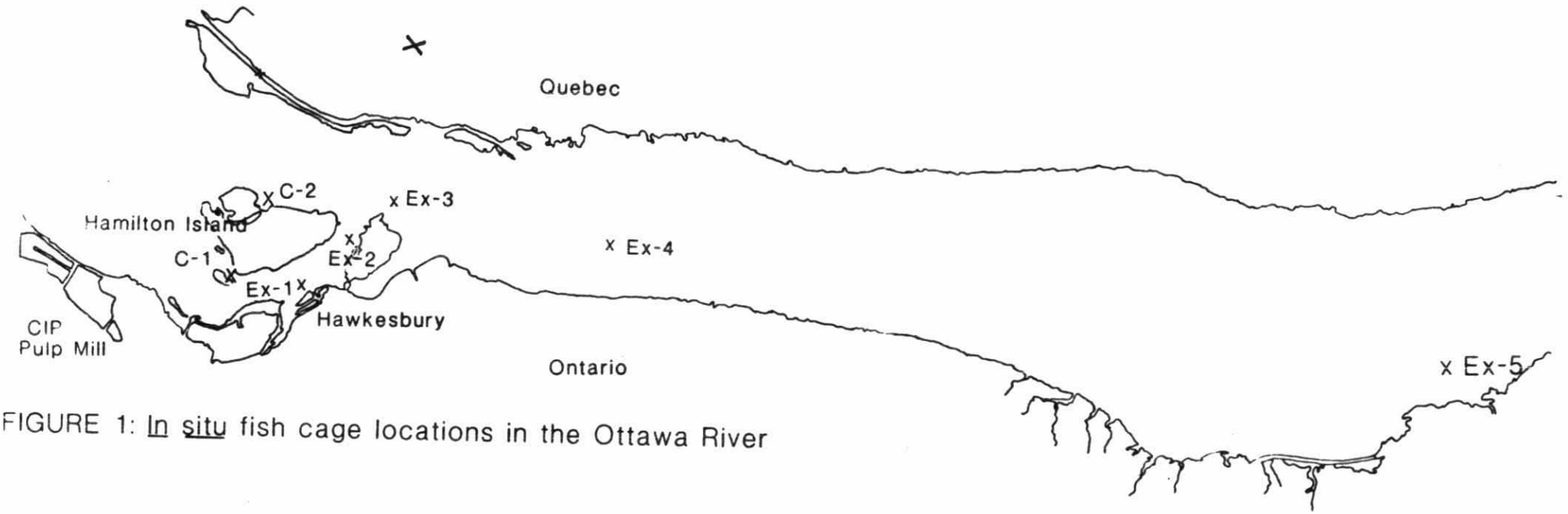


FIGURE 1: In situ fish cage locations in the Ottawa River

Two control sites were chosen, one on either side of Hamilton Island upstream of the mill discharge. Control site one (C1) was sited south of the island while C2 was sited on the north side.

The five exposure sites were selected so as to be in the centre of the plume at distances of 30m (Ex1), 500m (Ex2), 900m (Ex3), 2500m (Ex4), 8500m (Ex5) downstream from the outfall. Conductivity profiles across the river were measured with the exposure sites being located to correspond to the maximum effluent concentration at that point in the river. At each of the seven sites a float was anchored so that the exposure cages could be suspended in the top metre of the water column.

(b) In Situ Exposures

(i) Cages

The cages used in this study were constructed of a 3/4" polyvinyl-chloride pipe frame with a nylon mesh (1/4") bag. The cages were 1 metre triangles with a depth of 0.5 metre and had a volume of $0.4m^3$. The triangular shape helped reduce the resistance to the river's current. Fish for each portion of the study were held in separate cages.

(ii) Fish

Certified disease free rainbow trout (Salmo gairdneri) were used for the in situ acute lethality and tainting studies in the river as well as the final effluent bioassays conducted at the Toronto laboratory. Fish used in lethal tests averaged 4.8 $\pm$ 0.5 cm in length and weighed 1.1 $\pm$ 0.4 gm while those used in the tainting study were 29.6 $\pm$ 1.3 cm in length and weighed 316.6 $\pm$ 43.7 gm. All fish stocks for the in situ work were held in a mobile laboratory located at the Hawkesbury Water Treatment Plant where they were acclimated for six days prior to the study to raw Ottawa River water taken upstream of the CIP mill.

(iii) Lethal Evaluation

The acute lethality exposure was carried out over the 96 hour period from October 4-8, 1981. Fifty fish were placed in a cage at each of five sites (C1, C2, Ex1, Ex2, Ex3). The cages were checked at 24 hours and 96 hours for mortality. Any dead fish were removed.

(c) Tainting Evaluation

The tainting exposure started October 5 with fish placed in cages at all seven sites. Three fish were removed from all sites at 48 hours, killed, weighed, measured, cleaned, individually wrapped in aluminum foil and frozen until tested for tainting.

Tainting evaluations were conducted in accordance with the standard Toxicity Unit method (MOE, 1981) based on the American Society for Testing and Materials technique with slight modifications.

Panel members expressed a liking for fish and tasted unidentified cooked fish samples (including an unmarked control) to rank them according to a five point scale where "0" was the same or better than a known control sample and "4" represented a severely tainted sample. All samples were scored against a known control and ranked against a hidden control. Results were statistically evaluated using Wilcoxon's Modified nonparametric ANOVA. Panel scores (minus control values) were also used to develop "tainting-effluent concentration" relationships. Two taste test evaluations were completed, one including fish from all sites (A) and a second (B) with fish from exposure sites Ex 1,3 and 5 only.

(d) Chemical Sampling

Water samples were collected at all seven exposure sites at the surface and at one metre intervals to the river bottom. The final effluent from the lagoon was also sampled daily during the exposure period. Analyses were completed for sodium, chloride, conductivity, pH, BOD_5 and COD. The final effluent sample was also analysed for resin and fatty acids. Field measurements for pH, temperature, D.O. and conductivity were recorded daily at one metre intervals for each site to ensure that physical conditions were within fish tolerance limits.

(e) Laboratory Toxicity Tests

One hundred litre samples of the final effluent were collected daily and shipped to Toronto for rainbow trout 96hr LC50 and daphnia 48hr LC50 determinations using dechlorinated Toronto City tap water for dilution. On the final day a large volume of Ottawa River water was also collected and transported to Toronto as dilution water for comparative purposes. An additional series of three bioassay samples was collected December 8-9, 1981, along with Ottawa River water for further testing.

The rainbow trout used in all the static bioassays performed at the Rexdale lab were held in dechlorinated Toronto City tap water. Bioassay test procedures followed the EPS protocol (Environment Canada, 1980). Concentrations required to produce 50% lethality (LC50's) were calculated by probit analysis (Finney, 1971) to provide 95% confidence limits.

Daphnia magna first instar life stages were cultured in Toronto dilution water and exposed to a logarithmic serial dilution of CIP effluent using Toronto and Ottawa river water. Only one effluent sample (October 8, 1981) was tested. Ten 24 hour old daphnia were placed in nalgene containers with 100 mls of effluent solution and exposed for 48 hours at $20^{o} \pm 1^{o}C$ without aeration. Mortality was recorded and LC50's plotted in accordance with the same method used for fish data.

IV. RESULTS AND DISCUSSION

(a) Water Chemistry

The chemical analysis showed no significant ($p>0.05$) difference at each station from day-to-day or through the water column except for site Ex1. Average values over time and depth are given in Table 1.

It was observed that the plume location at Ex1 varied with wind and current conditions. This area was also found to produce highly variable readings by the River Systems Group (Draper, 1982).

(b) Acute Lethality

No mortality was observed at the control site north of Hamilton Island (C1) while limited mortality (4%) was recorded at the control site adjacent but upstream of the discharge (C2). Control mortality up to 10% is acceptable in standard test protocols but nonetheless is undesirable and should be more in line with that exhibited at Site C1 (nonlethal).

Fish mortality was observed at sites Ex1 (9.3%), Ex2 (42%) and Ex3 (13%). The lower mortality at Ex1 is probably a reflection of plume wandering closer to the discharge site while the other two sites were consistently exposed to the plume according to the Draper (1982) report. The above fish caging sites are contained within the effluent dispersion plume described by the $\geq$115 µmho isopleth plume which extended about 1250m downstream of the discharge (Draper, 1982).

Static fish bioassays completed at the Rexdale laboratory established the lethality of the CIP effluent (Table 3). Comparison of 96 hour LC50's generated with Toronto (12.9% v/v $\pm$ 2.8 C.I.) and Ottawa River water (7.5% v/v $\pm$ 3.3 C.I.) indicated similar responses ($p>0.05$) although toxicity tended to be greater with the softer Ottawa water (Table 4). The relationship of effluent toxicity increasing with the use of softer dilution water is consistent with results reported by McLeary, Walden and Munro (1979) who generated 96 hour LC50's exposing rainbow trout to pulp and paper effluents diluted with various natural waters from across Canada.

TABLE 1: CHEMICAL PARAMETERS RECORDED AT CONTROL AND EXPOSURE SITES IN THE OTTAWA RIVER
(VALUES ARE AVERAGED OVER TIME AND DEPTH)

Exposure Site	No. Samples	Na (mg/1)	Cl (mg/1)	SO_4 (mg/1)	pH	Conductivity (umhos/cm)
C1	20	3.50	3.60	12.50	7.37	113.9
C2	20	3.45	3.40	13.10	7.40	112.9
Ex1	20	6.85	6.55	18.43	6.17	141.5
Ex2	20	6.00	6.18	17.55	6.18	137.7
Ex3	20	5.90	5.80	16.95	6.27	134.9
Ex4	25	4.85	4.70	13.83	6.54	126.2
Ex5	20	4.40	4.50	13.20	6.66	126.9

* Data was homogeneous for time and depth ($p < 0.05$).

TABLE 2: CHEMICAL CHARACTERIZATION OF HAWKESBURY CIP FINAL DISCHARGE

Date	pH	BODs (mg/1)	COD (mg/1)	Cl (mg/1)	Na (mg/1)	SO_4 (mg/1)	Conductivity (umhos/cm)	Total Fatty Acid (mg/1)	Total Resin Acids (mg/1)
October 4	3.4	1750	5990	174.5	-	271	1800	0.0	0.52
5	3.3	1400	4334	154.5	-	211	1600	0.0	1.08
6	3.2	1700	6394	119.5	-	249	1700	0.0	0.86
7	3.6	1600	4977	154.0	-	233	1650	0.0	0.40
8	3.0	1350	4856	110.0	-	215	1550	0.0	0.84
(HRS)									
Dec. 8 800	3.7	1650	5940	123	198.0	253	1680	-	-
8 1600	3.1	680	2480	29	32.5	169	1690	-	-
9 800	3.1	1020	4200	122	130.0	223	1830	-	-

Comparison of upstream conductivity with that of the lethal effluent plume suggests that a 17-20% increase in background conductivity, due to the addition of CIP effluent, will produce a lethal response in fish exposed over 96 hours. A 20% increase in conductivity would correspond to an approximate 1% dilution of CIP effluent with Ottawa River water. Laboratory fish lethality results would therefore appear to underestimate the toxicity of the effluent undoubtedly due to the difference of constant effluent renewal at the cage sites. Static aerated tests may lose toxic volatiles and promote chemical degradation. Fish mortality was observed to occur within 12 hours in the LC50 concentration (10%) and within 1.5 hours in the highest prepared concentration (25%).

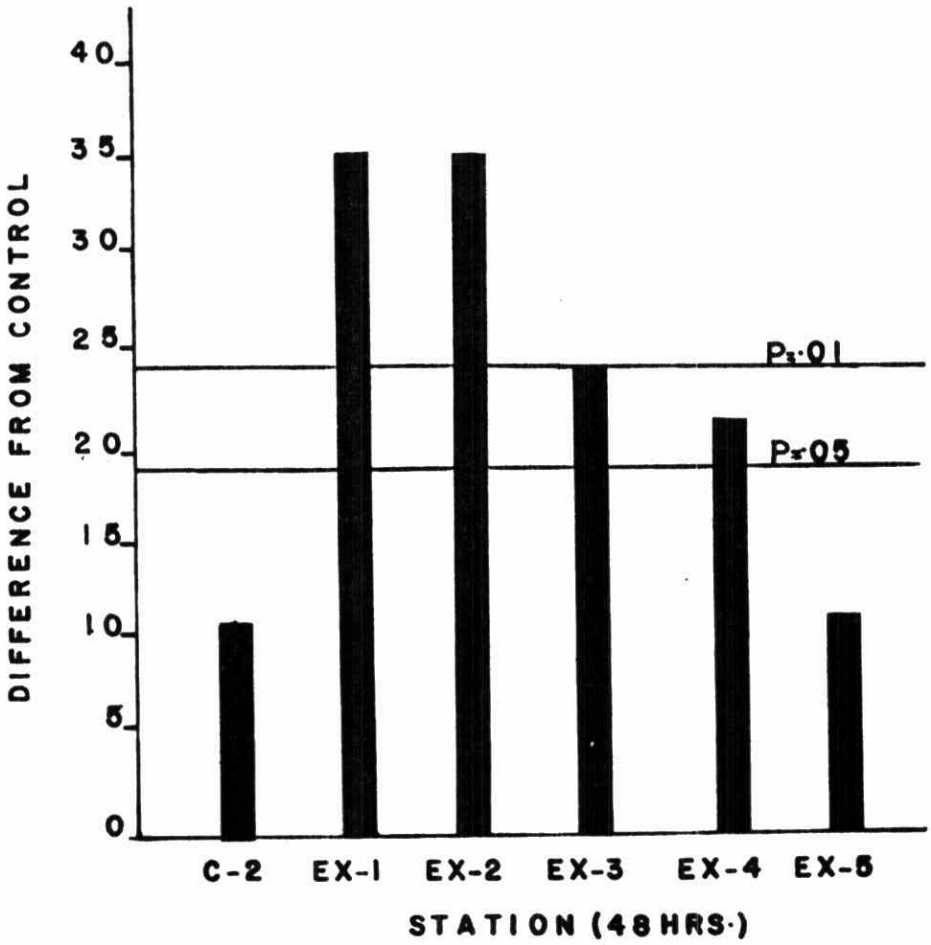
Daphnia magna also exposed to CIP effluent in static tests produced 48 hour LC50's of 9.8% in Toronto dilution water and 5.6% in Ottawa water illustrating the similar sensitivity of invertebrate food organisms to that of fish.

Resin acids, recognized pulp and paper toxicants, were measured in the final effluent (Table 2) but contributed only about one sixth of the toxicity exhibited in laboratory tests considering that the average 96 hour LC50 of resin acids for fish is 0.4 mg/L (Leach and Thackore, 1977).

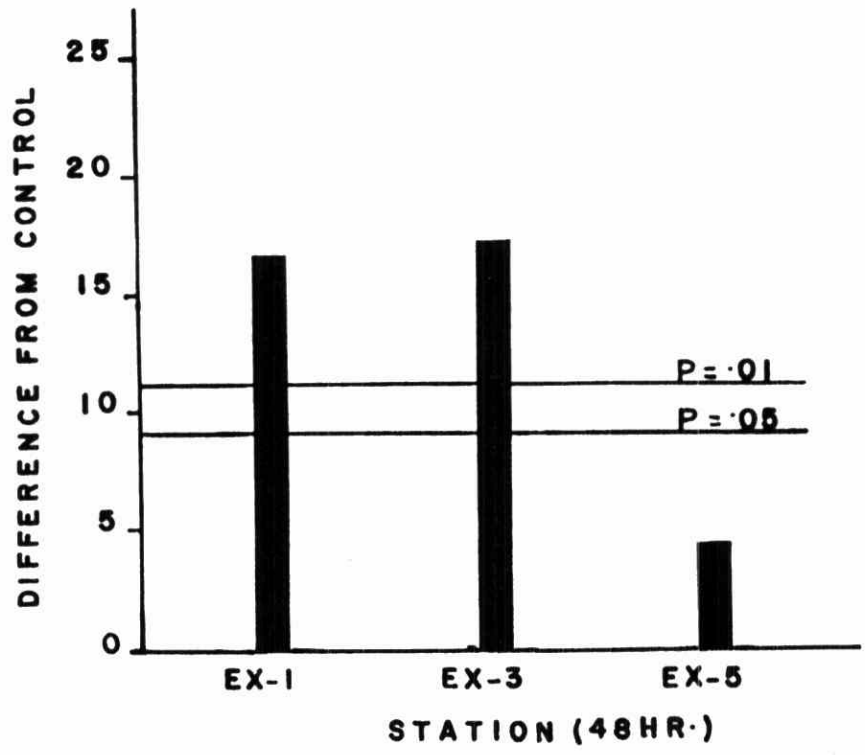
(c) Fish Tainting

Taste tests demonstrated significant tainting (p 0.05) in fish held at the first four stations (Ex1, 2, 3 and 4) for 48 hours in evaluation A and at Ex1 and 3 in evaluation B (Ex2 was not tested). No significant tainting was measured at Ex5 in either evaluation (Figure 2). Regression analysis of fish tainting scores for both evaluations plotted against cage site distances downstream of the discharge (Figure 3) indicates that fish tainting would be expected

FIGURE 2: Scores for Rainbow Trout tainting evaluations



Tainting Evaluation A



Tainting Evaluation B

FIGURE 3 : Tainting scores for fish exposed in the Ottawa River for 48 hours at increasing distances downstream of the CIP effluent discharge.

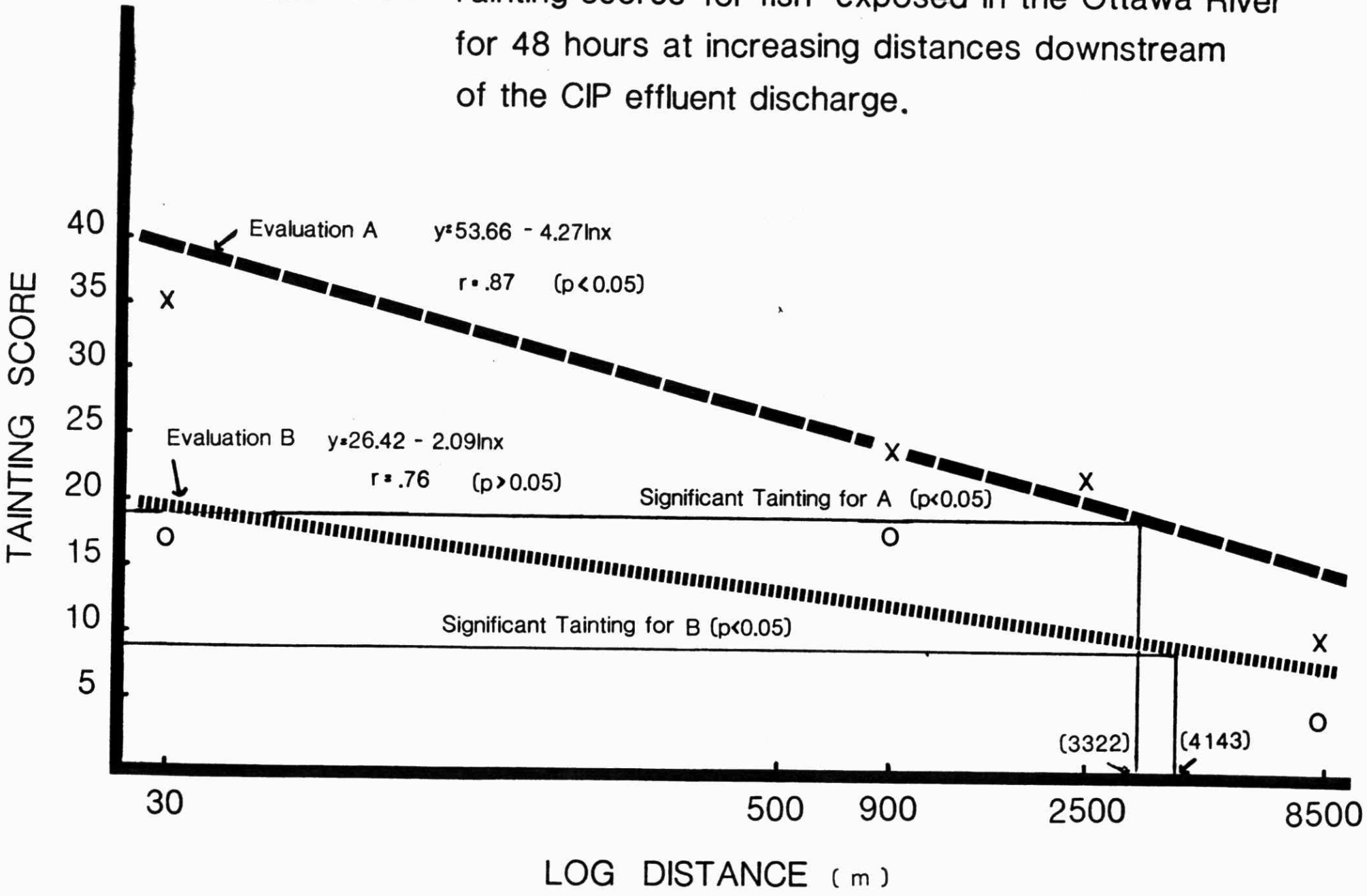


TABLE 3

CIP HAWKESBURY FINAL EFFLUENT USING TORONTO AND OTTAWA RIVER DILUTION WATERS

RAINBOW TROUT STATIC 96 HOUR LC50'S
(95% Confidence Limits)

Date	Toronto	Ottawa River
October 4	13.8 (10.9-17.6)	
October 5	15 (12.2-18.6)	
October 6	10.4 (6.9-15.8)	
October 7	16.4 (14.0-19.2)	
October 8	12.7 (9.8-16.4)	8.7 (5.0-15.00)
December 7	7.1 (5.0.10.0	5.8 (4.6-7.3)
December 8	18.2 (16.2-20.4)	9.8 (8.3-11.5)
December 9	9.8 (8.3-11.5)	5.8 (4.6-7.3)
$\bar{X}$	12.9	7.5
σ	3.69	2.04
95% C.I.	$\pm$ 2.83	$\pm$ 3.26

TABLE 4

CHEMICAL CHARACTERIZATION OF DILUTION WATER USED IN TOXICITY TESTS
(mg/l Unless Otherwise Indicated)

Parameter	Toronto	Ottawa River
Ca	46	15
K	1.5	1.0
Na	14	4
Mg	5	1
Cl	6.5	5.7
SO_4	26	12
Hardness ($CaCO_3$)	29	36
Alkalinity ($CaCO_3$)	29	36
Conductivity (uhmos)	340	112
pH	6.5	5.7

as far as 3.3km from the discharge based on interpretation of evaluation A ($p < 0.05$) and as far as 4.1km downstream based on evaluation B ($p > 0.05$). The fish tainting zone corresponds to the ≥ 106 umho plume described by Draper (1982) extending 3.8km downstream and represents an 8-12% (approximately 10%) increase in background conductivity.

V. CONCLUSIONS

(a) Lethality

The CIP effluent can be clearly demonstrated as acutely lethal to fish (96hr LC50 = 10%) and fish food organisms (48hr LC50 = 8%) as a result of laboratory bioassays. The zone of acute fish lethality was observed to extend 900m downstream of the CIP discharge. The acute lethality is expected to extend 1250m downstream according to dispersion studies.

The zone of acute lethality appears to correspond with a 20% increase in background conductivity due to CIP effluent discharge into the Ottawa River. Resins acids in the CIP effluent are estimated to contribute only about one sixth of the total effluent toxicity.

(b) Tainting

Fish held for 48 hours as far as 2.5km downstream of the CIP discharge were observed to be tainted.

Extrapolation of taste test data indicates that fish tainting extends as far as 3.3km downstream of the CIP discharge and is estimated to extend farther to 3.8km according to dispersion studies.

The zone of fish tainting appears to correspond with a 10% increase in background conductivity due to CIP effluent discharge into the Ottawa River.

(c) Water Management Violations

In situ toxicity and fish tainting test results demonstrate that the CIP waste discharge produces a mixing zone in the Ottawa River which is contrary to the Ontario Ministry of the Environment's Water Management* Policy 5 in that an area of acute fish lethality and fish tainting exists within the mixing zone.

The evidence of this study identifies a need for additional treatment of the CIP effluent to improve its overall quality.

* Water Management Goals, Policies, Objectives and Implementation Procedures of Ontario Ministry of the Environment.

VI. POST SCRIPT

Shortly after the completion of the Ministry field study, CIP ceased operations (December 1, 1982) at its Hawkesbury plant. Declines in market demands for cellophane and rayon resulted in the company being unable to sell 50% of its product and the soft economy was cited as the reason for closing.

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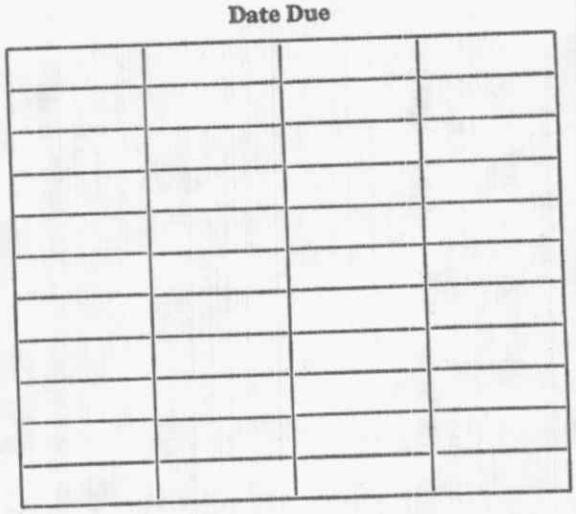

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